Hybrid renewable energy photovoltaic and darrieus VAWT as propulsion fuel of prototype catamaran ship

Budhy Setiawan, Ekananda Sulistyo Putra, Indrazno Siradjuddin
Electrical Engineering Department, State Polytechnic of Malang, Malang, Indonesia

Article Info

Article history:

Received Dec 22, 2020
Revised Mar 26, 2021
Accepted Jun 19, 2021

Keywords:

Hybrid renewable energy
Photovoltaic module
Ship's propulsion
Wind turbine generator

ABSTRACT

Currently, marine transportation in the world still uses fossil fuels. In addition to running low on supplies, fossil fuels also cause emissions that cause global warming. Sea transportation generates around 1,000 million tonnes of CO_2 emissions. Therefore, the exploration of alternative energy is becoming a popular research direction. Several renewable energy sources include solar and wind energy. Indonesia has an average wind speed of above 8 m/s at sea. Also, the energy potential of the sun is around 4.8 kWh/m^2. Based on the potential of these renewable energy sources, this study discusses the potential of renewable energy sources from sunlight and wind, which are implemented in the prototype catamaran ship. The results obtained from the experiment, the total energy of photovoltaic (PV) and wind turbine generators is 774 Wh. This energy can be used to charge a battery with a battery specification of 35Ah for 6 hours.

Corresponding Author:

Ekananda Sulistyo Putra
Electrical Engineering Department
State Polytechnic of Malang
Jl. Soekarno-Hatta No. 9, Malang 65141, Indonesia
Email: ekananda_putra@polinema.ac.id

1. INTRODUCTION

Currently, the majority of electrical energy is produced from fossils; almost 85% of all energy comes from fossil fuels [1], [2]. One of the sectors that use fossil fuels is sea transportation. More than 95% of civil ships use diesel engines for propulsion [3]. Sea transport emissions around 1,000 million tonnes of CO2 yearly and contribute to 2.5% of global warming [4], [5]. Therefore, exploration of alternative energy, alternative fuels, energy conservation, and environmental protection technology is becoming a popular research direction [3], [6]-[8]. Renewable energy comes from natural resources such as sunlight, wind, tide and geothermal, which is replenished naturally [9]-[11].

The wind speed map based on the WindSat data, in Indonesia has wind speeds from 5 m/s to 10 m/s or greater than the minimum wind speed to drive wind turbine generator, which is 4 m/s [2], [12]**.** Apart from wind energy, Indonesia has an average solar radiation potential around 4.8 kWh/m^2/day with a monthly variation of about 9% [13]. Wind turbines are alternative energy technologies that are able to convert wind energy into electrical energy [14], [15]. There are two types of wind turbines, namely horizontal-vertical axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). The working principle of the HAWT wind turbine is based on the lift force of the wind energy while the VAWT wind turbine is based on the drag force that occurs due to wind movement [16], [17]. HAWT is widely used for higher production volumes that require a large investment and occupy more space for installation compared to VAWT [18], [19]. VAWT requires a low-cost investment and less space for installation compared to HAWT [16], [17]. Photovoltaic (PV) module is a semiconductor consisting of a dio [20] de p-n junction when exposed to sunlight, will create

electrical energy that can be utilized, this energy conversion is called the photoelectric effect [5], [21]-[23]. Both renewable energy sources will be stored in lithium batteries [24], [25]. Using a lithium battery because it has the highest energy to weight and energy to space ratio of modern rechargeable batteries and is relatively light [26], [27].

In this research discusses the potential use of the that renewable energy sources which are implemented in the catamaran prototype with specifications length of arc 170 cm, beam 100 cm and depth 32 cm. Catamaran ship is a twin-hull ship [28], where the two hulls are connected with substantial deck construction and stretch on it to withstand large bending moments and shear forces and work towards the midline (Centerline) ship [29], [30]. The catamaran model uses a battery to supply energy to the DC motor. They were charging the battery using renewable energy sources of solar energy and wind turbine generators. 2 pieces of PV used with a specification of 100 wp per PV, while for wind turbines using the VAWT type.

2. PROPOSED METHOD

In this research, a catamaran ship model uses renewable energy to drive ship propulsion. The methodology used is collecting PV and wind turbine performance data using a microcontroller directly, simulating a controller to combine PV energy and wind turbines. Next, look at the power used by the motor and simulate the energy used by the ship.

2.1. Energy system block diagram

The block diagram system is shown in Figure 1. Wind energy will drive the wind turbine, which will drive the generator. The generator will produce AC voltage which is then rectified using a rectifier to produce DC voltage. The output voltage generated by the PV and generator in the wind turbine is connected to the buck-boost converter. Buck-boost converter is used to adjust the voltage so that the voltage is stable with a value of 14 Volts to charge the battery for driving power on the catamaran model. The specifications of the components used in this study are shown in Table 1 for wind turbine generator specifications, Table 2 for blade specifications, Table 3 for PV specifications, Table 4 for battery specifications and Table 5 for motor specification.

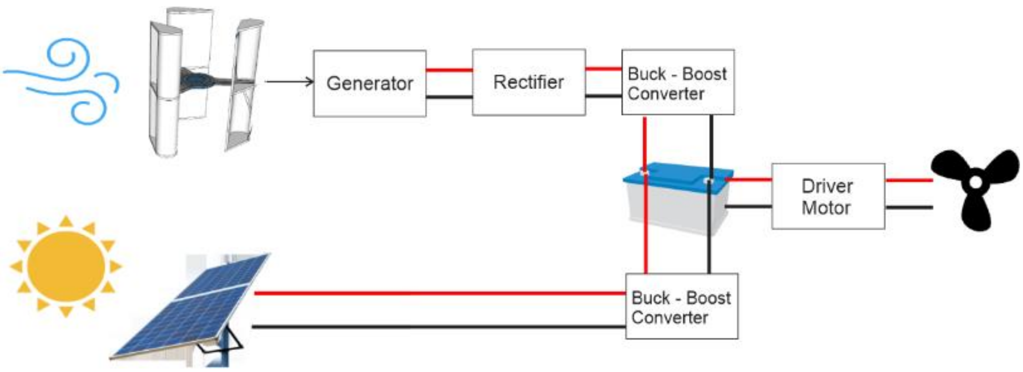

Figure 1. Energy system block diagram

Table 1. VAWT specification

No	Specification	Value
1	Type	Darrieus VAWT
2	Diameter	120 cm
3	Height	200 cm
4	Material	Alumunium Pipe Stainless steel Alumunium Dural

Table 2. Blade specification

No	Specification	Value
1	Type	0015
2	Blade Amount	3
3	Material	Balsa Wood
4	Height	150 cm
5	Length	16 cm
6	Width	1.9 cm

Table 3. Photovoltaic module specification

No	Specification	Value
1	Max Power	100 Watt
2	Open Circuit Voltage	19.2 Volt
3	Short Circuit Current	6.87 Ampere
4	Max Power Voltage	16 Volt
5	Max Power Current	6.25 Ampere

Table 4. Battery specification

No	Specification	Value
1	Capacity	35 Ah
2	Voltage	12.8 Volt
3	Weight	3.8 Kg
4	Dimension	348 mm x 261 mm x 30 mm

Table 5. Motor specification

No	Specification	Value
1	Voltage	12 Volt
2	KV Value	460 KV
3	Speed	5300 rpm
4	Diameter	90 mm
5	Type	Submerge BLDC Motor

2.2. Hardware design

Figure 2 is the electronics components used in the research. Three current and voltage sensors are used to determine the energy of PV, wind turbine, and accumulator. The wind direction sensor and wind sensor are used to determine wind direction and determine wind speed in real-time, respectively. Optocoupler is used to determine the RPM of wind turbines. The RF transmitter is used to send the data that has been obtained by microcontroller to the ground station. Figure 3 is a design of a catamaran ship prototype with LoA specifications 170 cm, beam 100 cm, and depth 32 cm.

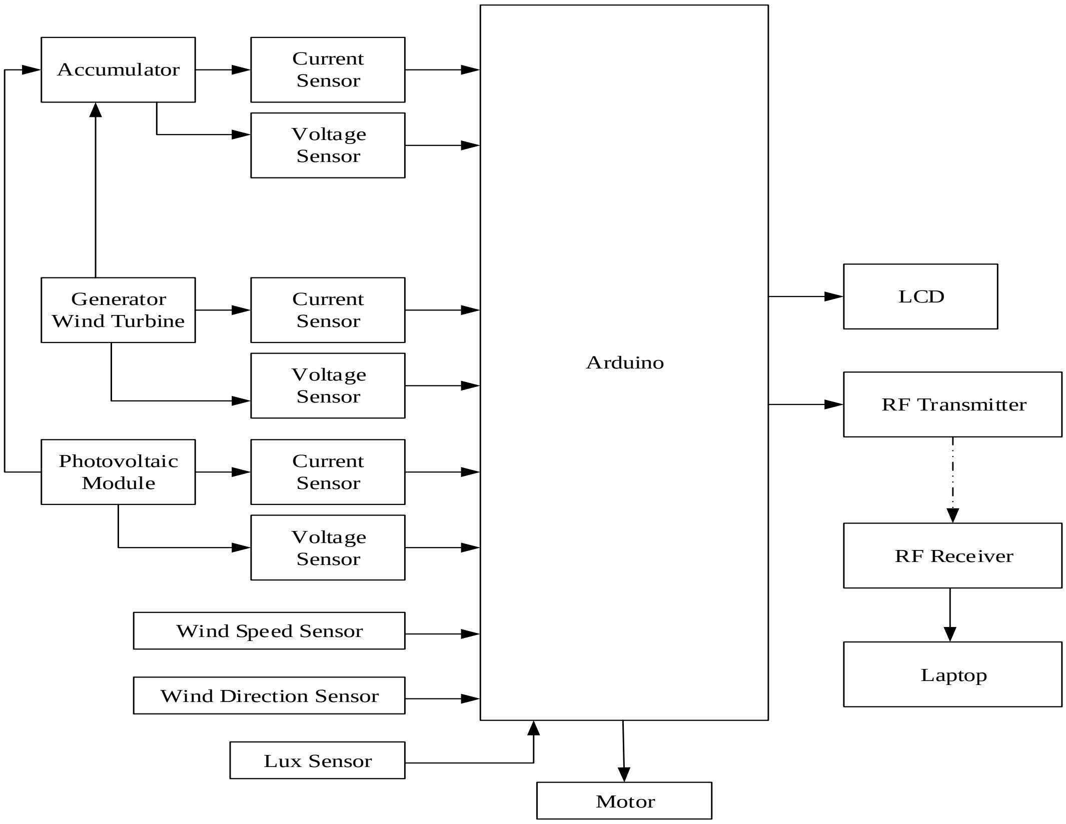

Figure 2. Electronics data acquisition design

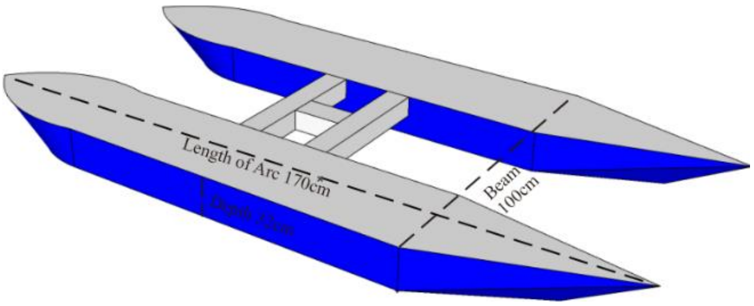

Figure 3. Ship mechanical design

The planned draft is about 15cm, so that the ship's deadweight tonnage value is around 85 kg. Deadweight tonnage means the total weight of the ship (mechanical weight and payload) that can be transported by the ship. The prototype of this ship is made using fiber and resin with a maximum weight of prototype catamaran ship is 17 Kg, using 2 BLDC motors with the specifications in Table 5.

3. RESULTS AND DISCUSSION

3.1. Result of wind speed identification

Identification of wind speed using a data logger for 3 days. Then these results will be calculated the average per hour. It was found that the lowest wind speed is around 0.4 m/s and the highest wind speed is around 4.65 m/s. So that the average wind speed is about 2.71 m/s. The graph of the wind speed is shown in Figure 4.

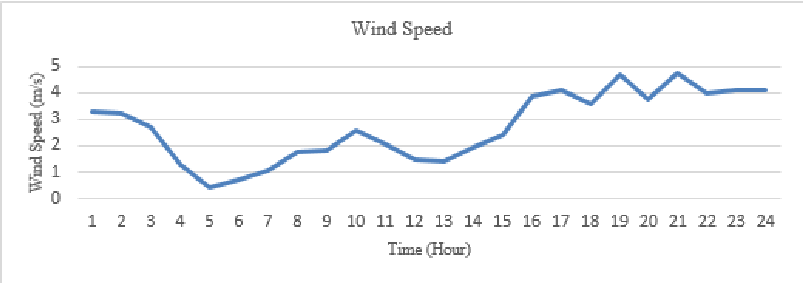

Figure 4. Wind speed

From the experimental results obtained, the maximum power that can be generated by the wind turbine generator is 39 watts, which is when the wind speed is around 4.6 m/s. The energy produced was about 354 Wh for one day of the experiment. The graph of the power generated by the wind turbine generator is described in Figure 5.

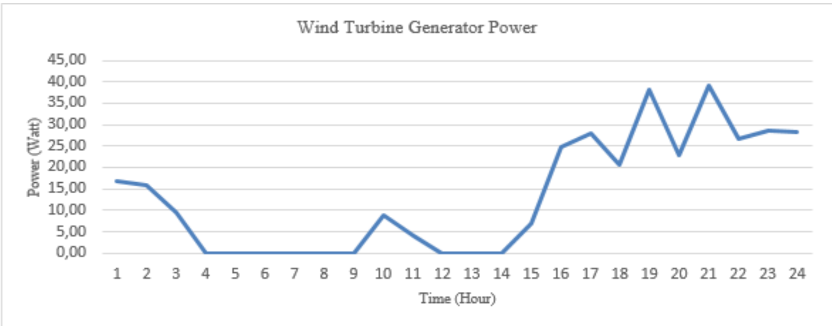

Figure 5. Wind turbine generator power

3.2. Results of photovoltaic identification

PV module performance identification was carried out for three days, from 09.00 to 15.50 hours. In this measurement using 2 PV installed in parallel, the load used is a lithium battery, voltage and current data will be saved to the data logger using a microcontroller as shown in Figure 6.

From the results of the PV performance test, it is described in Figure 7, which shows the lux value in the time range from 08.56 to 15.50 hours. The highest lux value was obtained at 11:15, which is around 110,000 lux and the average lux value at the time of testing was approximately 66,365 lux. Based on Figure 8 shows the value of power against time. The highest power is obtained around 75 Watts. Meanwhile, the average power during the testing period is around 60.07 Watt. From the experiments, the PV power used is 200 Wp, while the results of the PV test can produce 420 Wh.

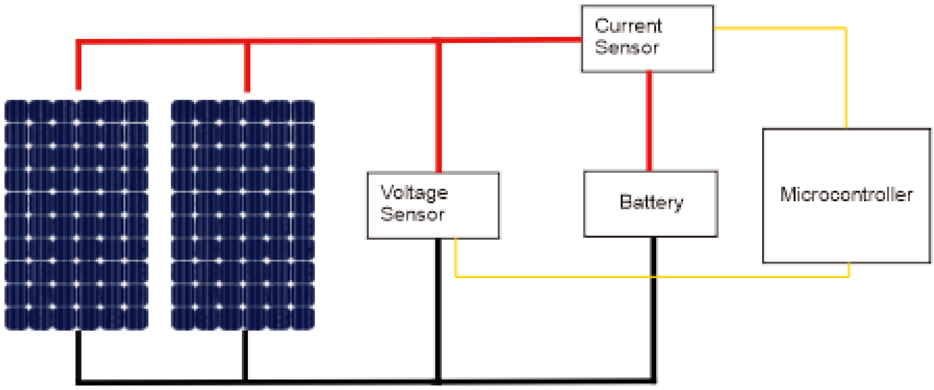

Figure 6. Battery charging by PV

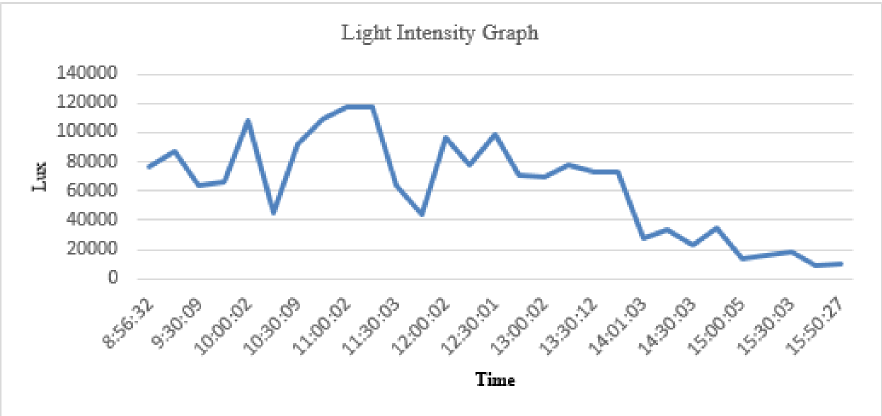

Figure 7. Day light itensity

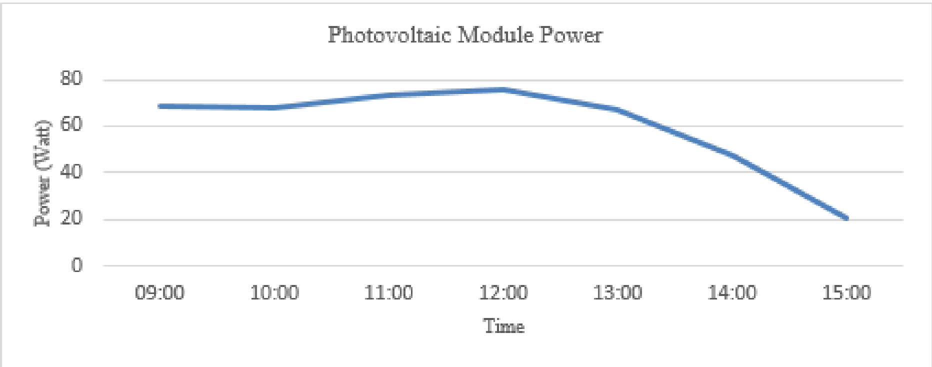

Figure 8. Photovoltaic module power

3.3. Propeler motor identification

From the motor, testing is done by tying the ship model and changing the throttle value on the remote. Next, observe the current required by the motor and the thrust that produced by the motor. The results obtained are shown in the Table 6 and Figure 9.

Table 6. BLDC motor test results

Throtle (%)	Voltage (Volt)	Current (A)	Thrust (Kg)	Power (Watt)
10	12.7	2.2	3.4	27.94
25	12.8	5.1	5.1	65.28
50	12.7	10	7	127
75	12.6	20.4	13	257.04
100	12.4	38	18	474

Based on Figure 9, the value of motor power to changes in the value of the throttle on the remote. From the experiments that have been carried out, the maximum power value is 474 Watt. The next test is the thrust motor. The results obtained are described in the Figure 10.

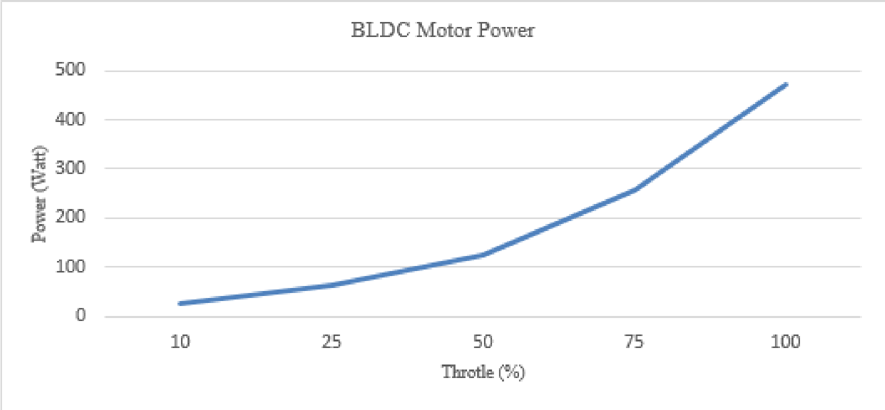

Figure 9. BLDC motor power

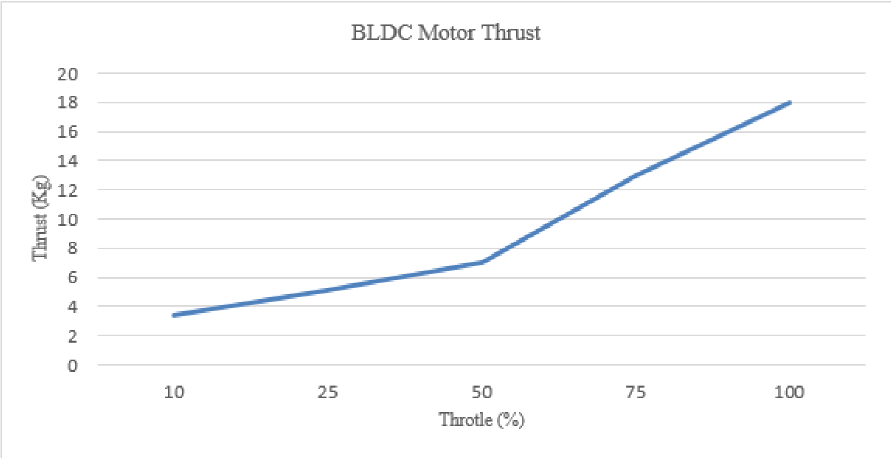

Figure 10. BLDC motor thrust

Based on Figure 10, the value of motor thrust to changes in the value of the throttle on the remote. From the experiments that have been done, the maximum power value is 18 Kg which is shown in Figure 11. From the graph above shows the ship speed when the load changes are given. The maximum speed of the ship with weight payload 3 Kg is 1.81 m/s (3.5 Knots). With weight payload 10 kg, the ship speed is 1.3 m/s (2.57 Knots). At a payload of 15 kg, the ship speed is 1.07 m/s (2.07 Knots).

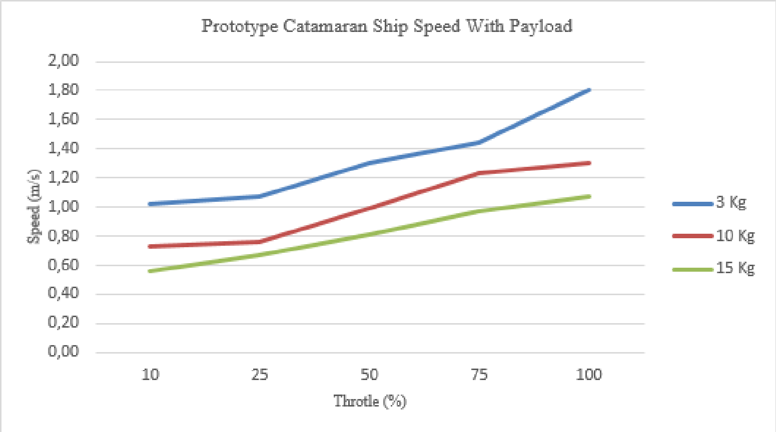

Figure 11. Prototype catamaran ship speed with payload

3.4. Energy simulation

From the experiments conducted, it is obtained the PV power and wind turbine generator power which is described in Figure 12. The battery has a capacity of 35Ah and 100% DoD. Which shows that the battery is capable of producing a current of 35 Amperes continuously within 1 hour. From the identification results of PV, wind turbine, and motor parameters obtained as shown in the Table 7.

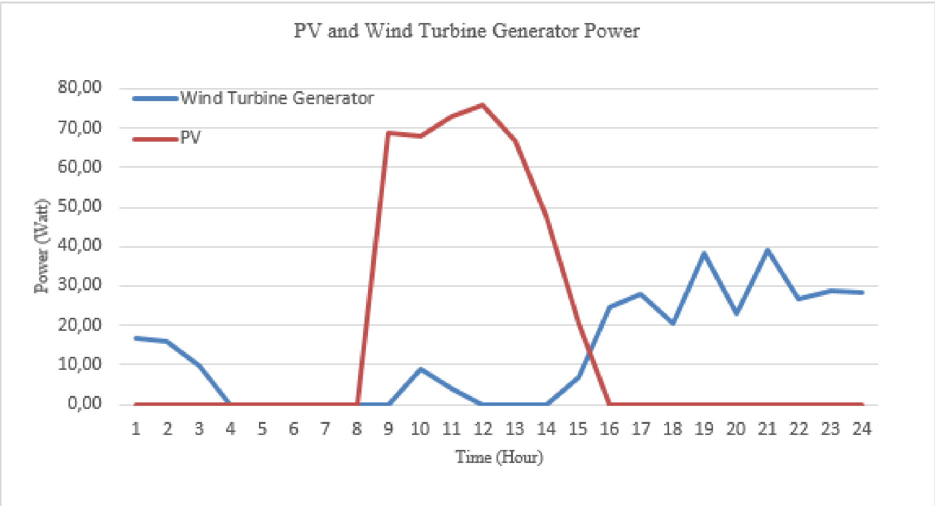

Figure 12. PV and wind turbine power generation

Table 7. Energy and power parameters

No	Parameters	Value
1	PV Energy	420 Wh
2	Wind Turbine Generator Energy	354 Wh
3	Motor Power	474 W
4	Battery Energy	448 Wh

From Table 7, it is found that the battery time can work when the motor is used as shown in (1)-(3):

$$I_{motor} = \frac{P_{motor}}{V} \tag{1}$$

$$I_{motor} = \frac{474\,Watt}{12.8\,Volt} = 37\ Ampere \tag{2}$$

$$Time = \frac{35\,Ah}{37\,Ah} = 0.945\,Hour = 56{,}7\,Minutes \quad (3)$$

From the above calculations, it is obtained, that the value of the battery discharge time, when used maximum PWM for 56.7 minutes. Furthermore, for the measure of the battery charging time. PV energy is obtained during the 7-hour test, so the average power that can be generated is 60 Watts. At the same time, wind turbine energy is obtained from the test results for 24 hours so that the power produced is 14.75 Watt. The total power generated by the system is 74.75 watts.

$$P_{total} = P_{pv} + P_{wind\ turbine\ generator} \quad (4)$$

$$I = \frac{P_{total}}{V} \quad (5)$$

$$I = \frac{74.75}{12.8} = 5.8\,Ampere \quad (6)$$

$$Time = \frac{35\,Ah}{5.8\,Ah} = 6\,Hour \quad (7)$$

Then it takes about 6 hours to charge the battery fully.

4. CONCLUSION

In this study, the main objective is to see the ability to use solar and wind as the main energy of the catamaran prototype that has been made with a Maximum total weight is 34 Kg with details 15.2 Kg for mechanical of prototype, 15 Kg for payload, and 3.8 Kg for battery. From the experiment results, the total energy of PV and wind turbine generators is 774 Wh. This energy can be used to charge a battery with a battery specification of 35Ah for 6 hours. Meanwhile, when the battery is full, it can supply the motor with a power of 474 Watt for 56.7 minutes at a speed of 1.81 m/s (3.5 Knots) when the payload weight is 3 kg and when the payload is 15 kg, the ship speed is about 1.07 m/s (2.07 Knots).

APPENDIX

Prototype catamaran ship testing

Darrieus VAWT

Machanical prototype catamaran ship with PV

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